An Experimental investigation of jet noise from septa(e) nozzles

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Outline of talk:

Introduction

Experimental Facility

Results and Discussion

Summary

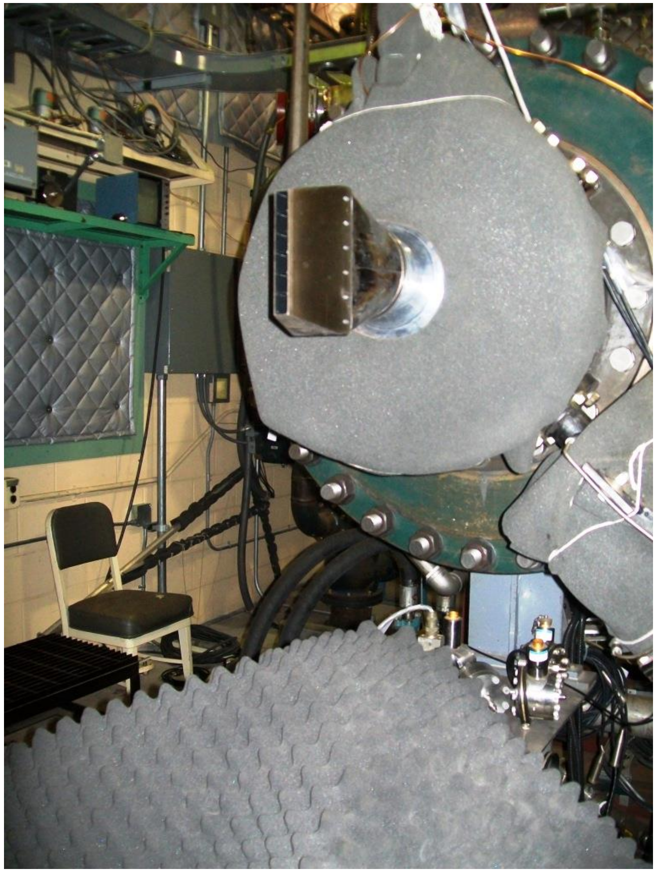
Distributed Propulsion

(From Felder, Kim & Brown 2009)

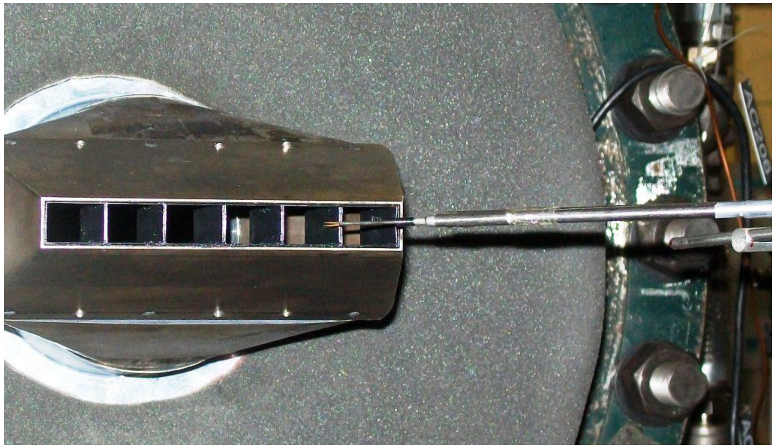
In one (hybrid) version of the concept each septum is driven by an electric fan

Concern about impact on noise. Will noise be greater than that from a equivalent single jet ?

Experimental Facility



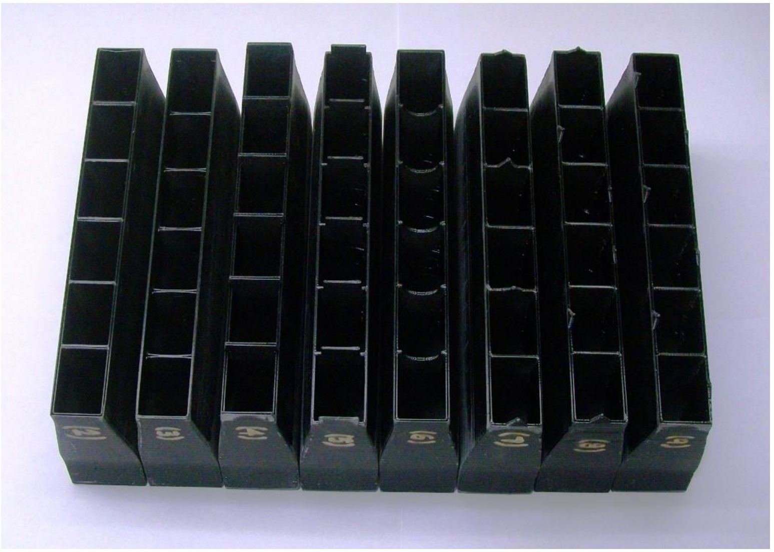
Open Jet rig (CW17)



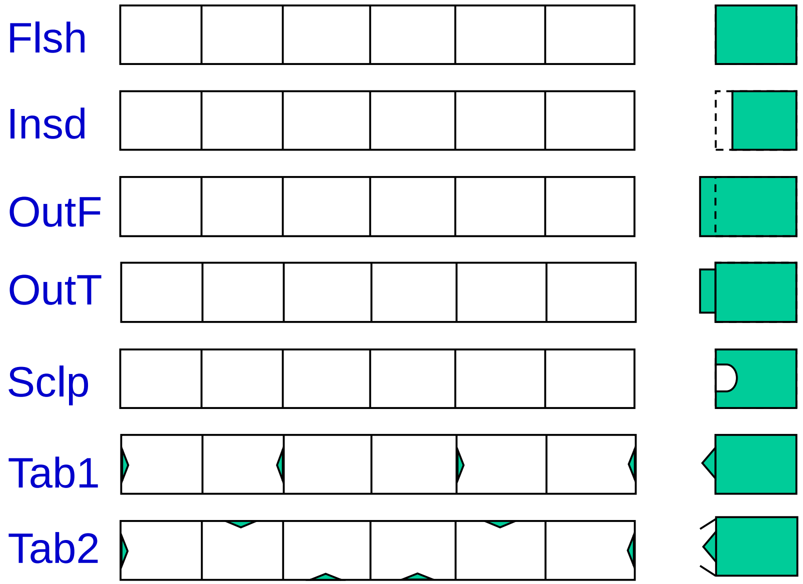
Close-up view of nozzle and HW

- **Up to about 500 kPa allowed**
- **Microphones overhead**
- **8:1 rectangular nozzle (14.1 cm x 1.68 cm)**
- **Inserts made by 3-D printing**

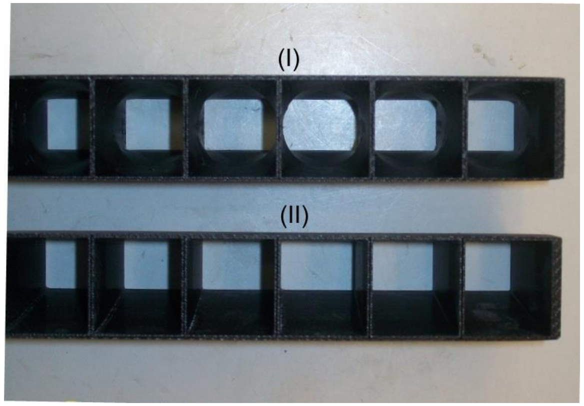
Experimental Facility (inserts)



Picture of 8 inserts



Schematic of exit shapes

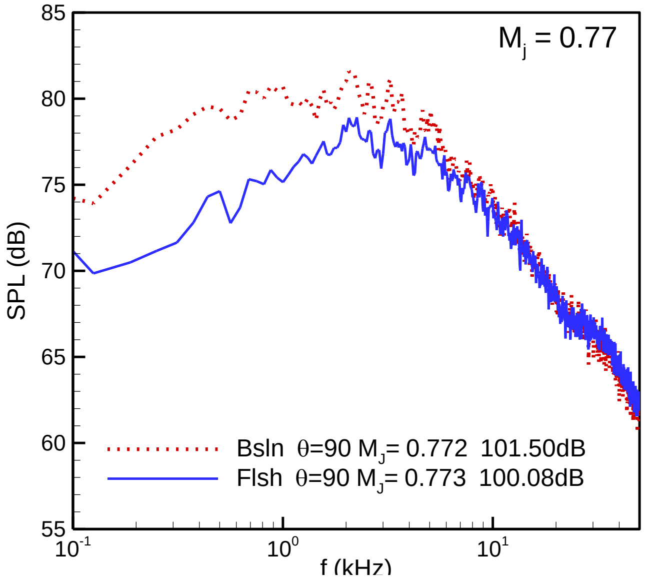


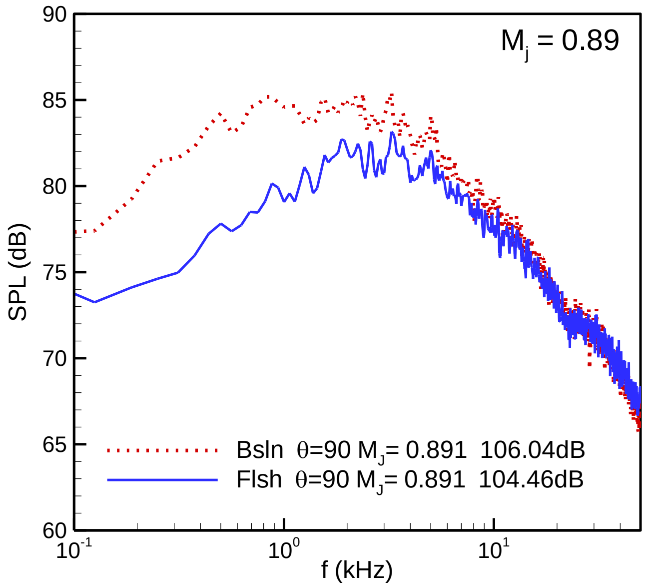
Internal geometry design I and design II

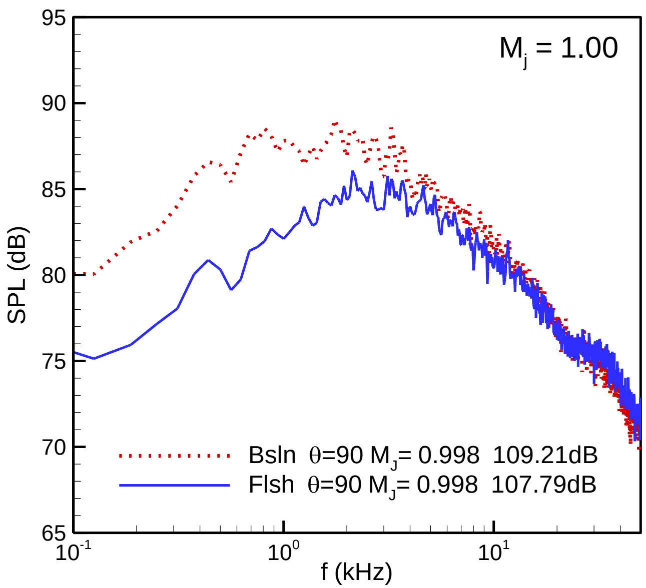
-Different exit shapes examined for maximum noise reduction

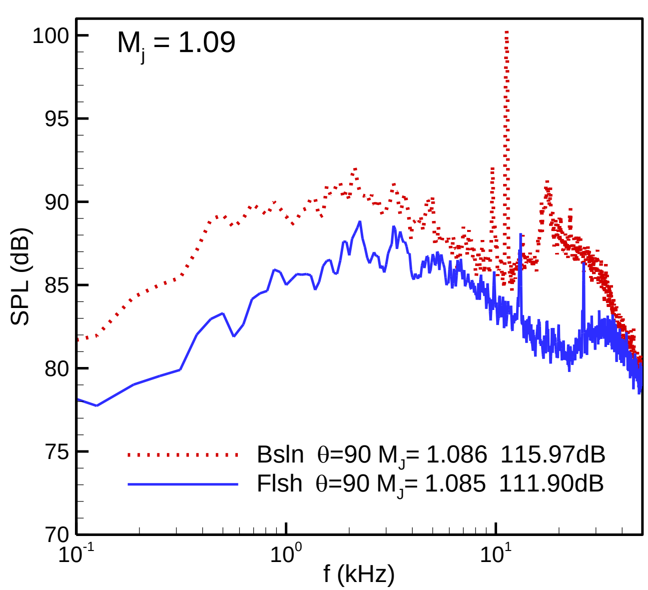
-Number of septa varied with Design II

SPL Spectra comparison: Baseline vs. Flsh cases





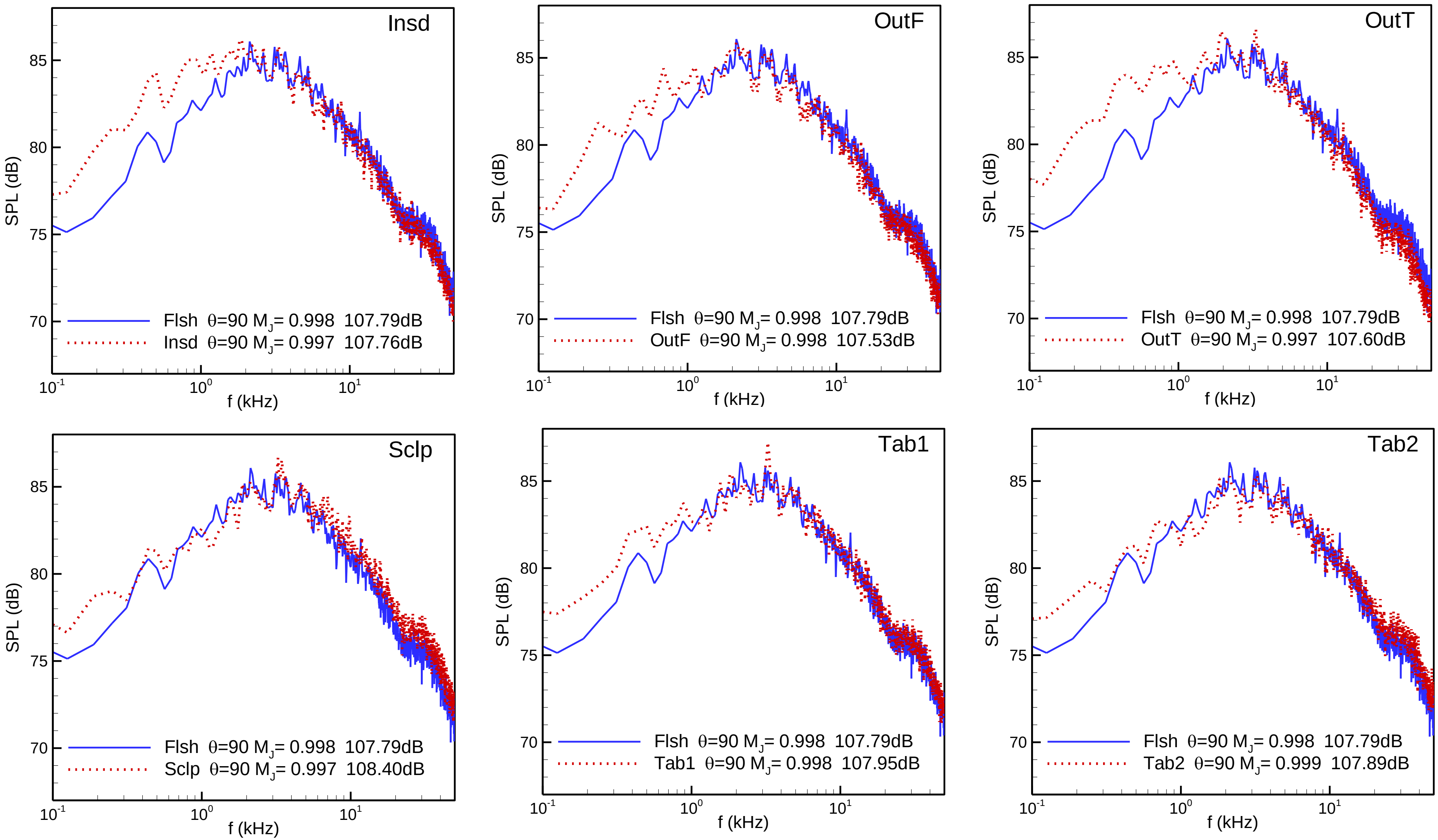




Lower noise on low frequency end for the Flsh case, at all M_j.

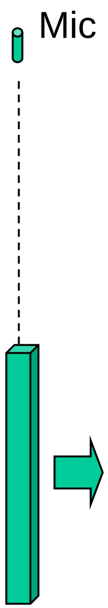
Not accounted for by exit area reduction (11% smaller D_{eq} => 1.3 dB)

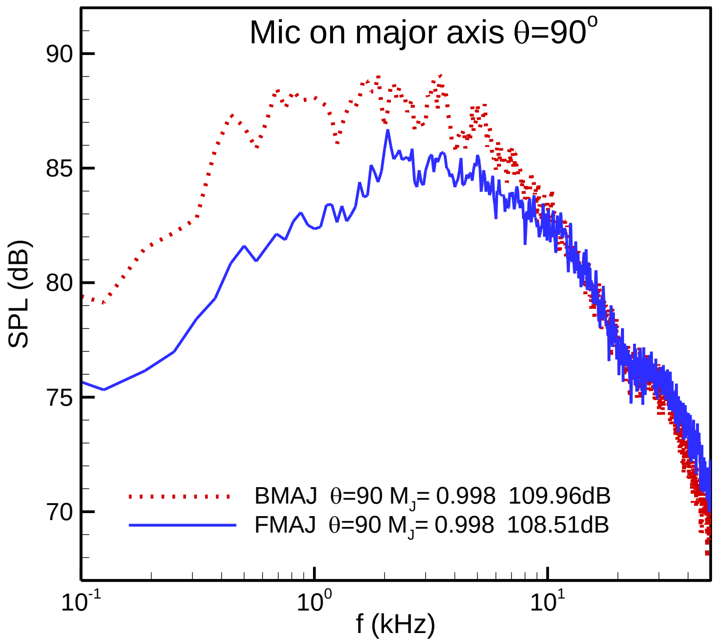
SPL Spectra comparison: Flsh vs other cases at M_j=1



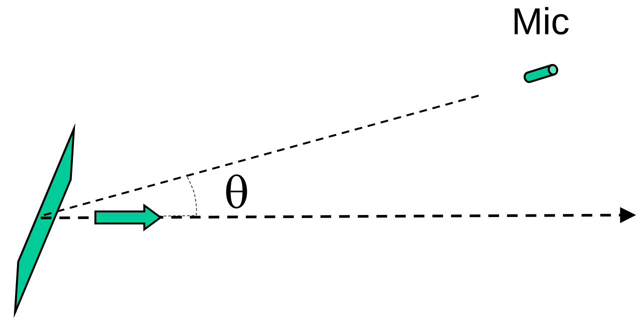
Maximum noise reduction with Flsh case. Sclp and Tab cases have comparable result.

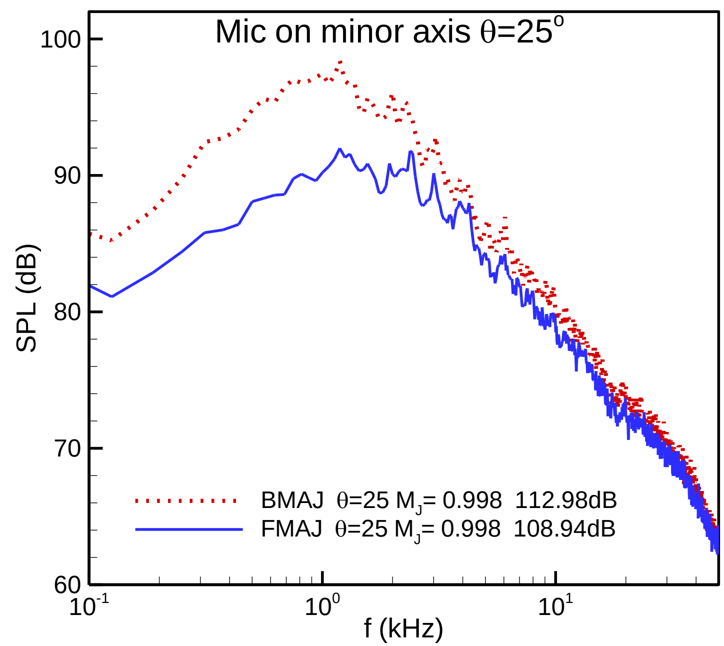
SPL Spectra Flsh vs Baseline at other angular locations; M_j=1





Narrow side (ϕ=90°); θ=90°



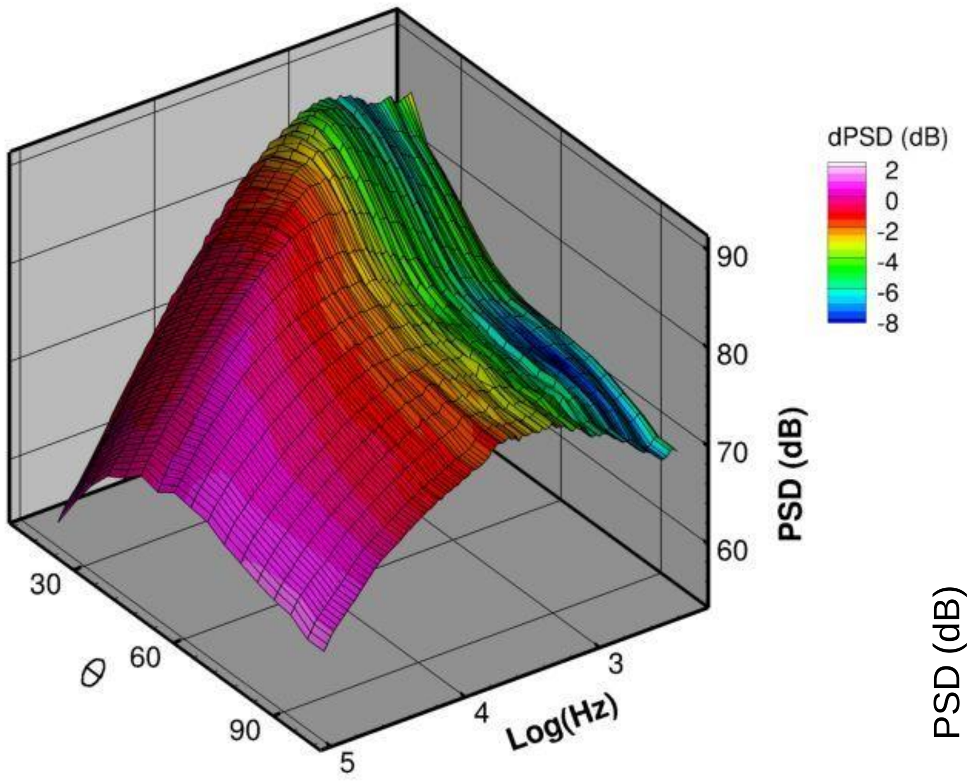


Broad side (ϕ=0°); θ=25°

Flsh case exhibit similar noise reduction at other azimuthal (ϕ) and polar (θ) locations

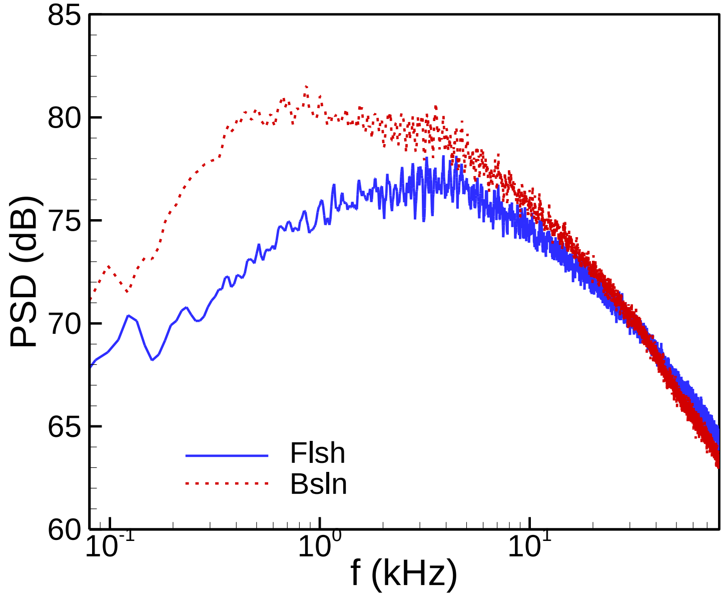
SPL Spectra data measured in the AAPL

Flsh vs. Baseline cases; M_j=0.99



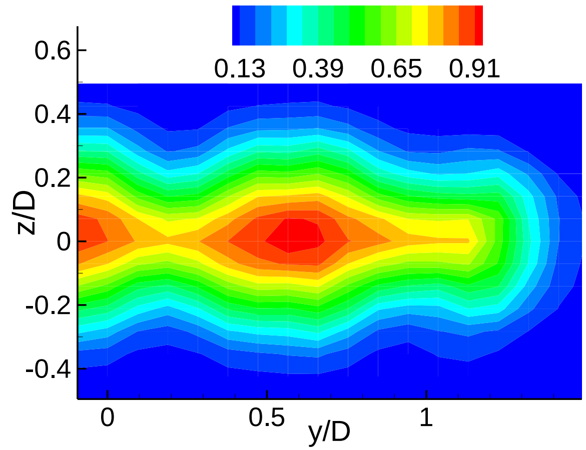
Carpet plot of PSD
Broad side (ϕ=0°)
24 θ locations

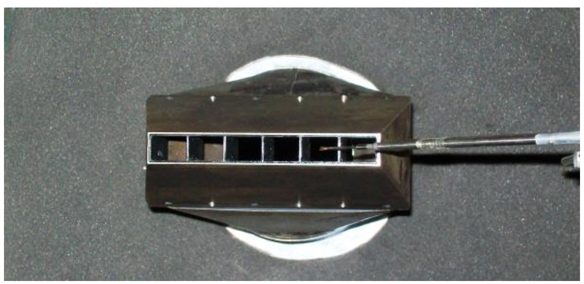
Observation in CW17 is confirmed by accurate data taken in the AAPL

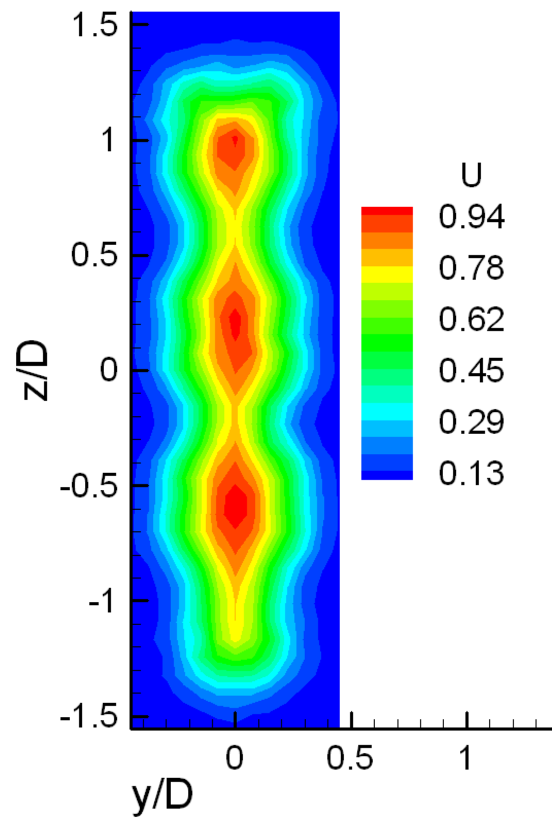


Direct comparison at ϕ=0°, θ=90°

U/U_j contours at x/D=2, M_j=0.265



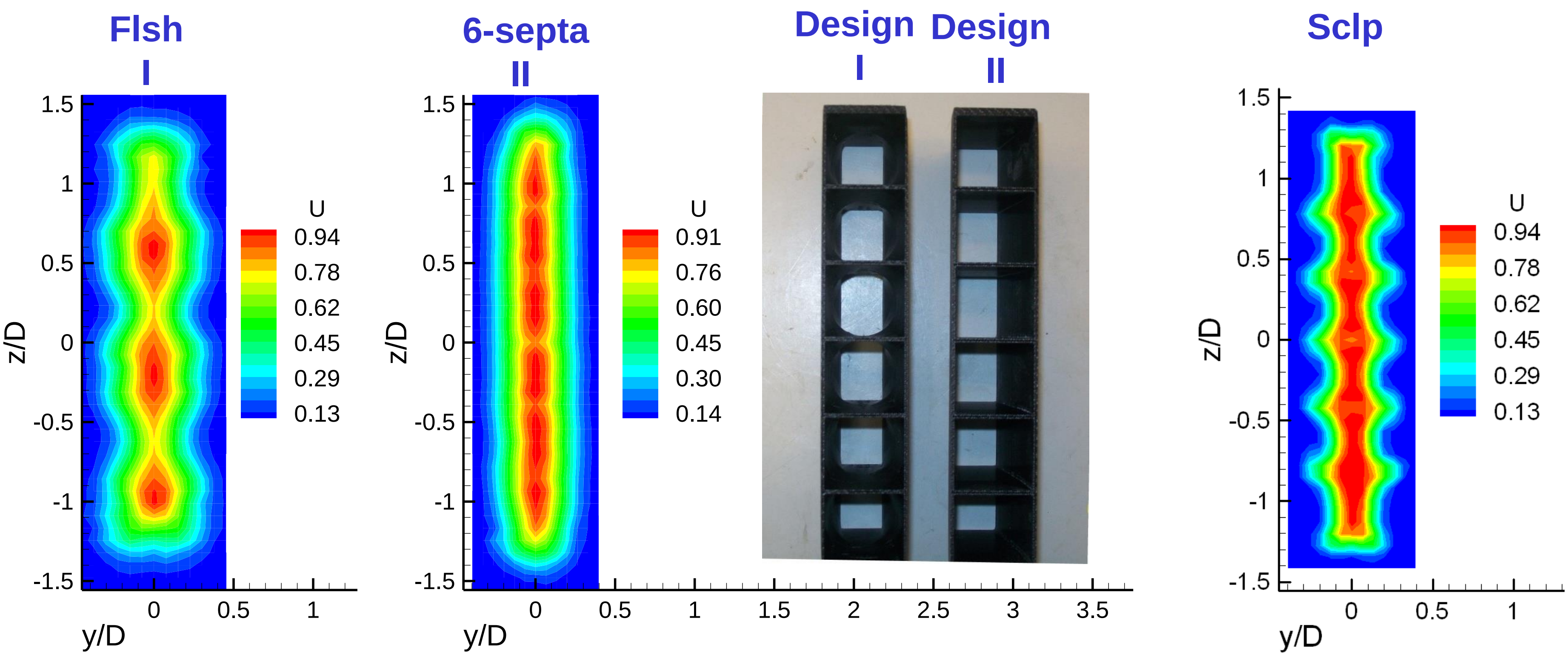




For reasons not yet understood, an asymmetry develops. The pairing of cells is likely due to streamwise vortex dynamics.

U contours at x/D=2; M_j =0.265
6-septa (flush) design I and II and Sclp case

Design I: rectangular-circular-rectangular passage
Design II: rectangular passage thru



No such pairing with design II case. Note only 5 cells for Sclp case.

Cross-sectional distributions of *U* at different *x*

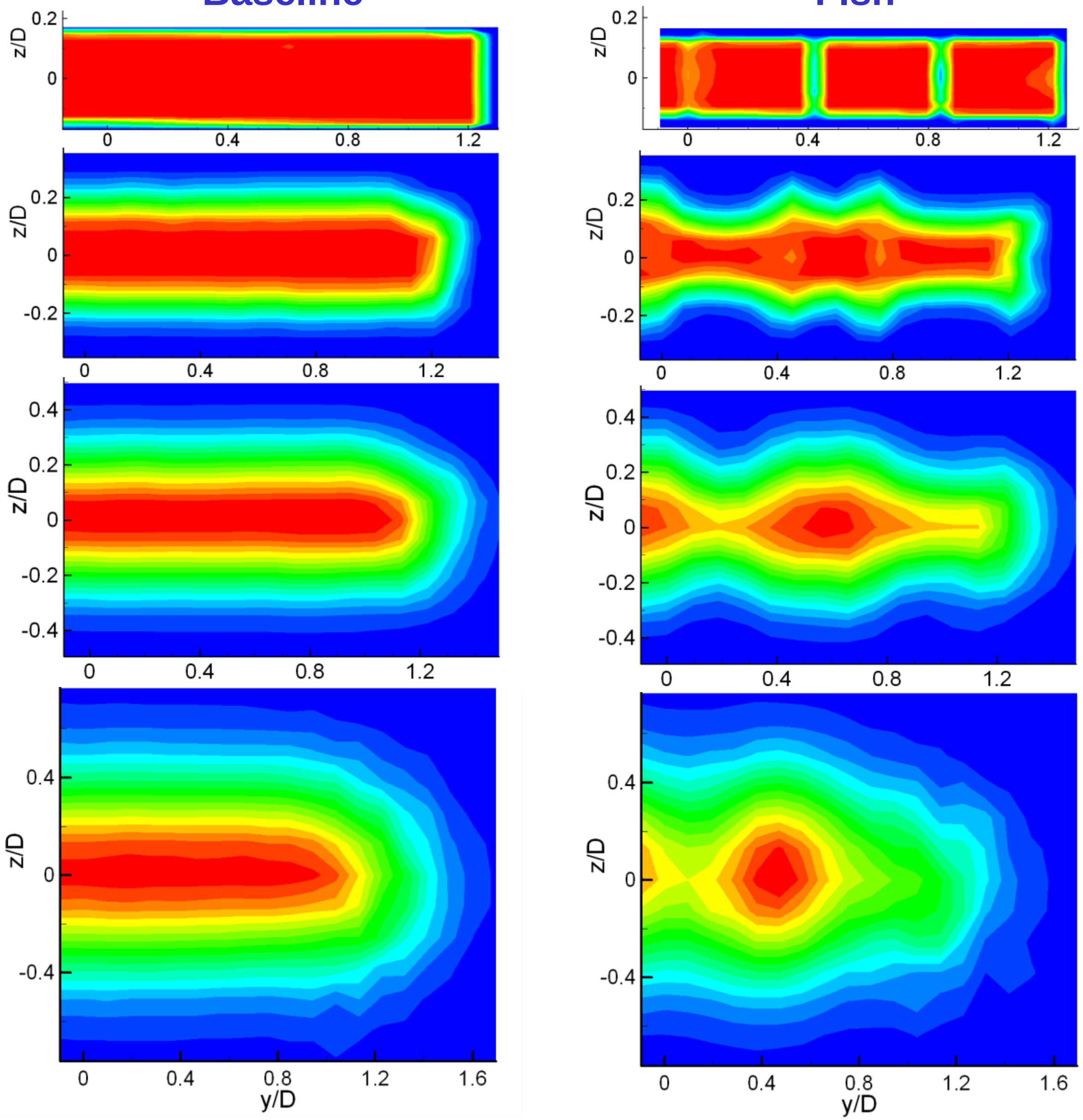
Baseline | **Flsh**

x/D=0.04

x/D=1

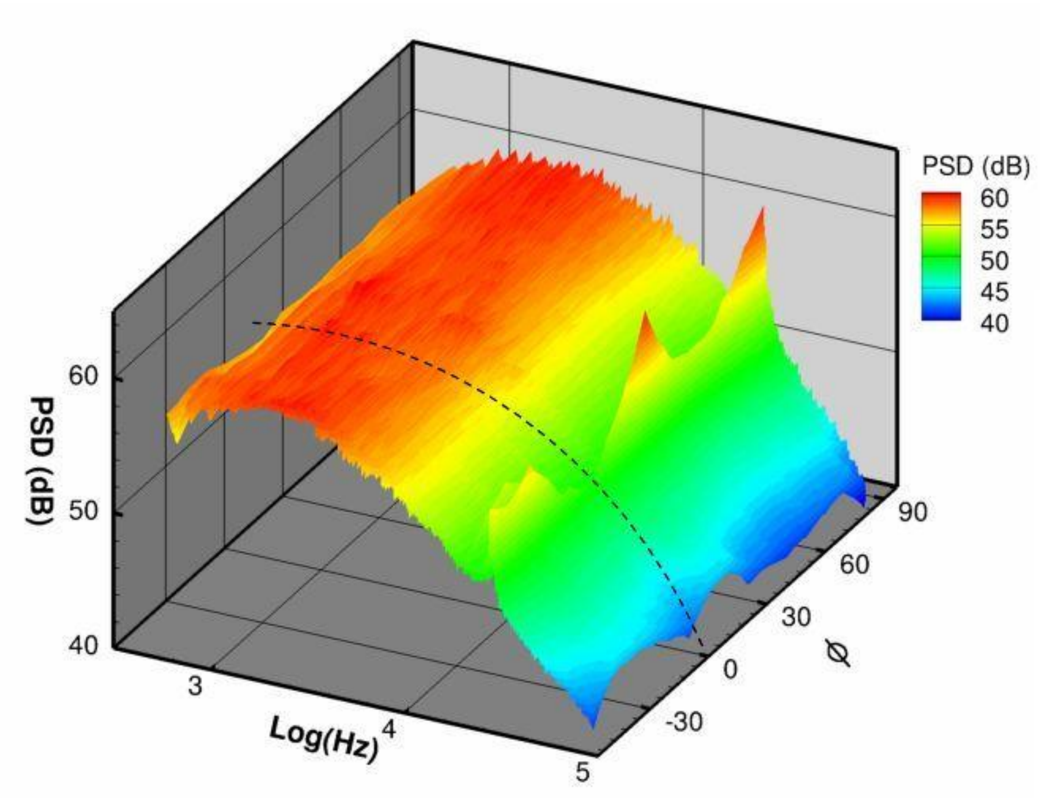
x/D=2

x/D=4



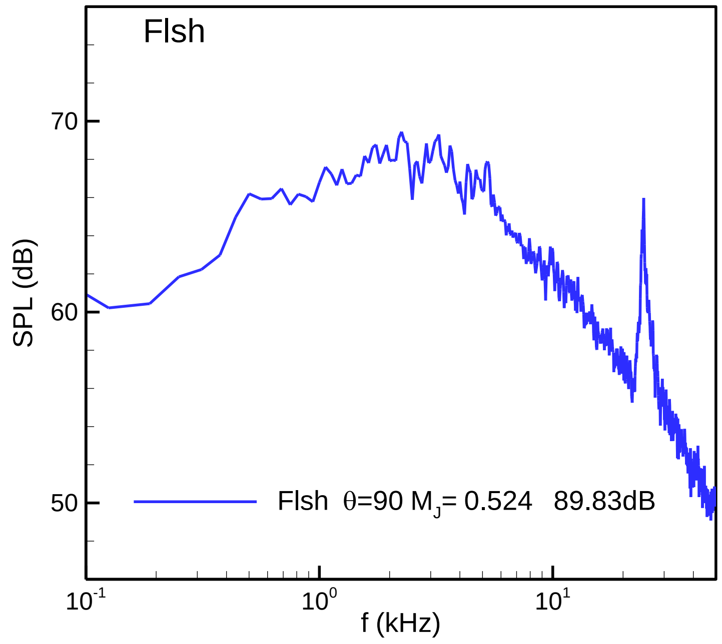
Detailed profiles of *U* and *u'* in paper. By x/D=16 flowfield is seen to become axi-symmetric for both cases

SPL Spectra data for different ϕ ; θ= 90º
Flsh case; M_j=0.52



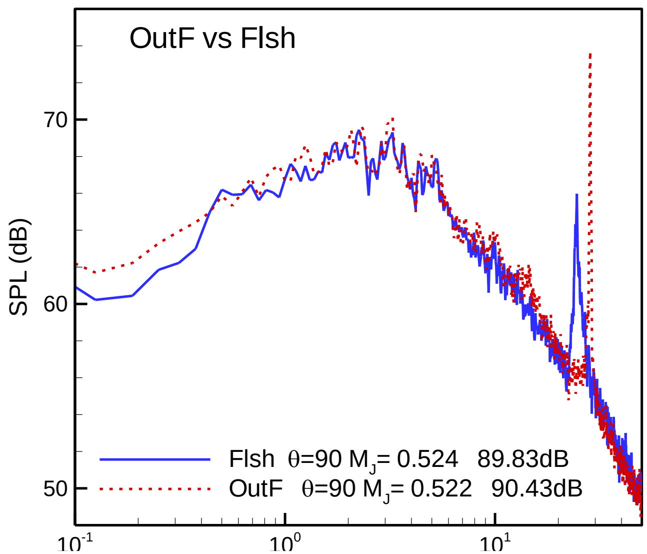
Carpet plot of PSD
24 ϕ locations
AAPL data

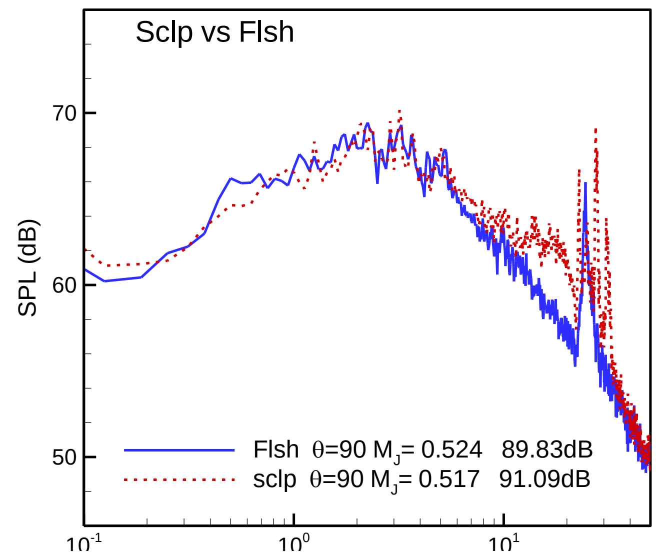
Earlier measurement in CW17 (ϕ=0) missed the spectral peak. When nozzle turned 90° peak appeared

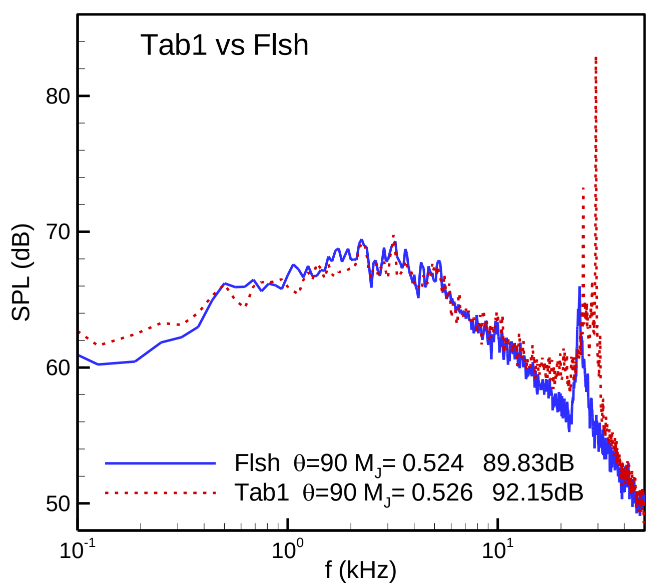


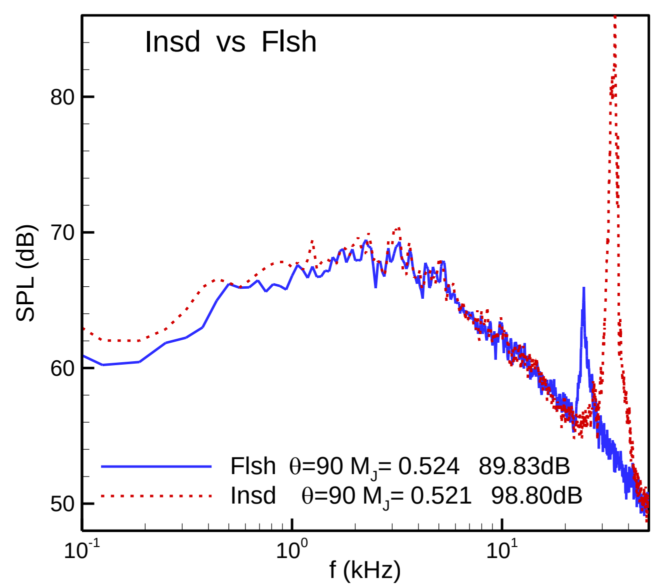
CW17 data on major axis (ϕ=90°)

SPL Spectra at M_j=0.52 on major axis for four different inserts compared to Flsh case





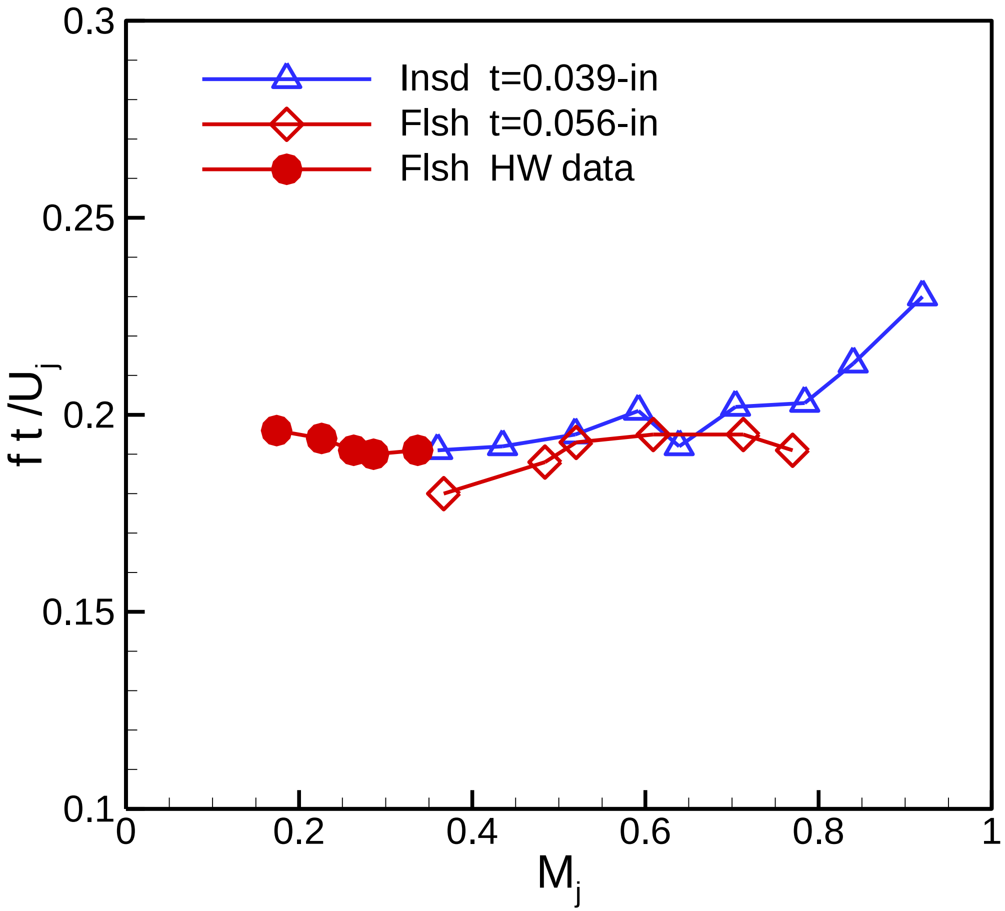


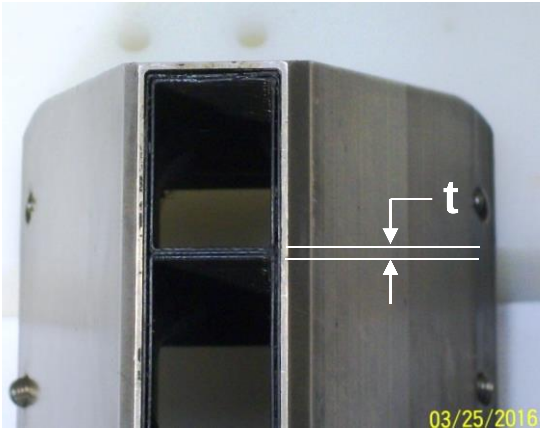


All inserts yield the high-freq spectral peak at low M_j. It is most intense with the Insd case

Strouhal number corresponding to spectral peaks

Data for Flsh and Insd cases
t = trailing edge thickness of partition
(Microphone as well as HW data)





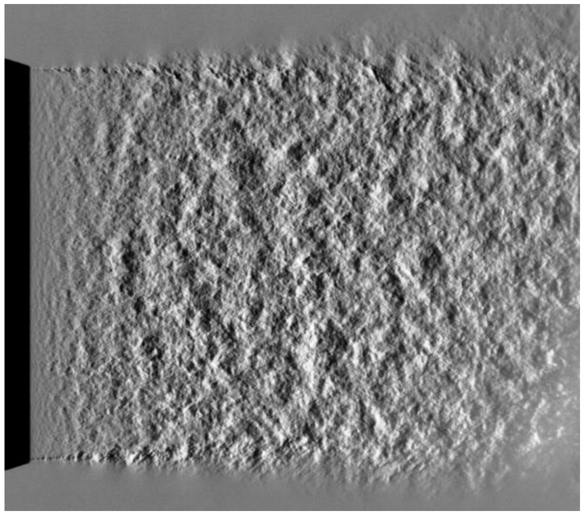
These data clearly suggest the high-frequency spectral peak is due to Karman vortex shedding from the TE of the partitions.

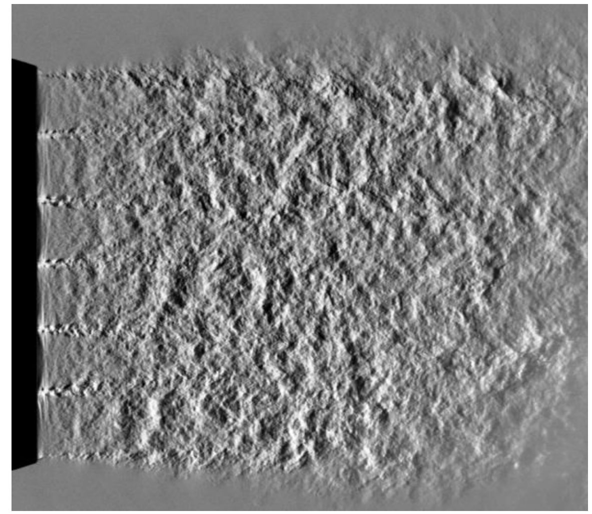
Schlieren pictures of flowfield M_j=1.00

Baseline and Flsh cases

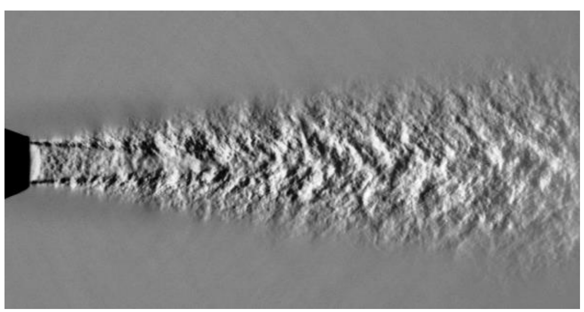
Baseline **Flsh**

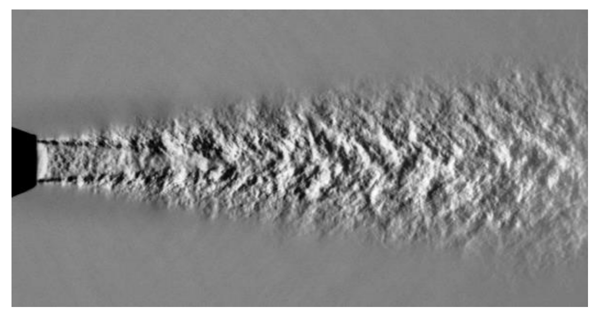
Major axis plane





Minor axis plane

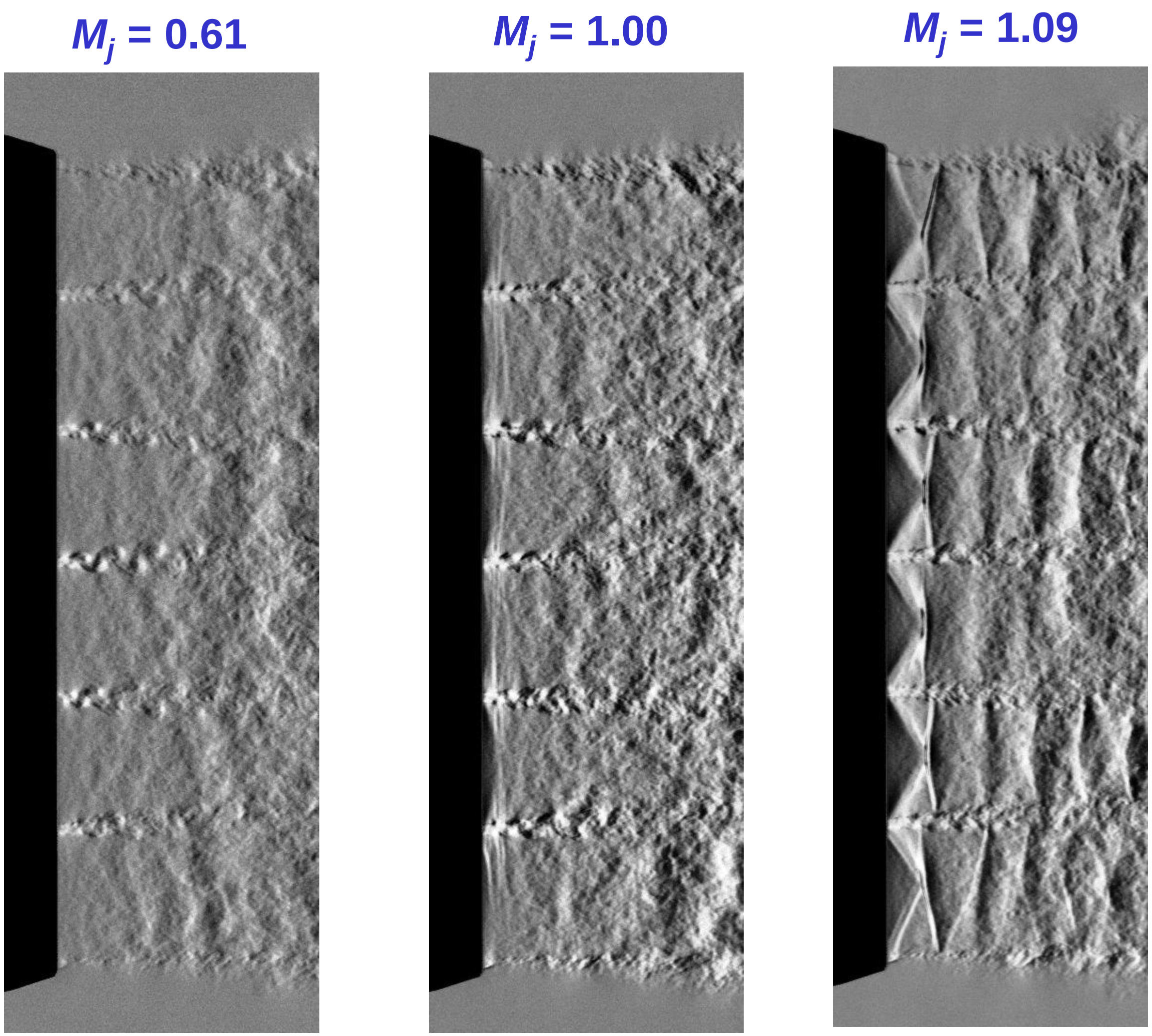




The Flsh case exhibit vortex shedding from the TE of partitions

Schlieren pictures of flowfield

Flsh case, major axis plane



Zoomed-in pictures show the asymmetric vortex shedding that is persistent even at supersonic condition with the presence of shocks

Conclusions

Nozzle with septa is quieter than corresponding baseline nozzle.

Cellular flow structure for the septa case (design I) goes through a curious evolution downstream where adjacent cells pair.

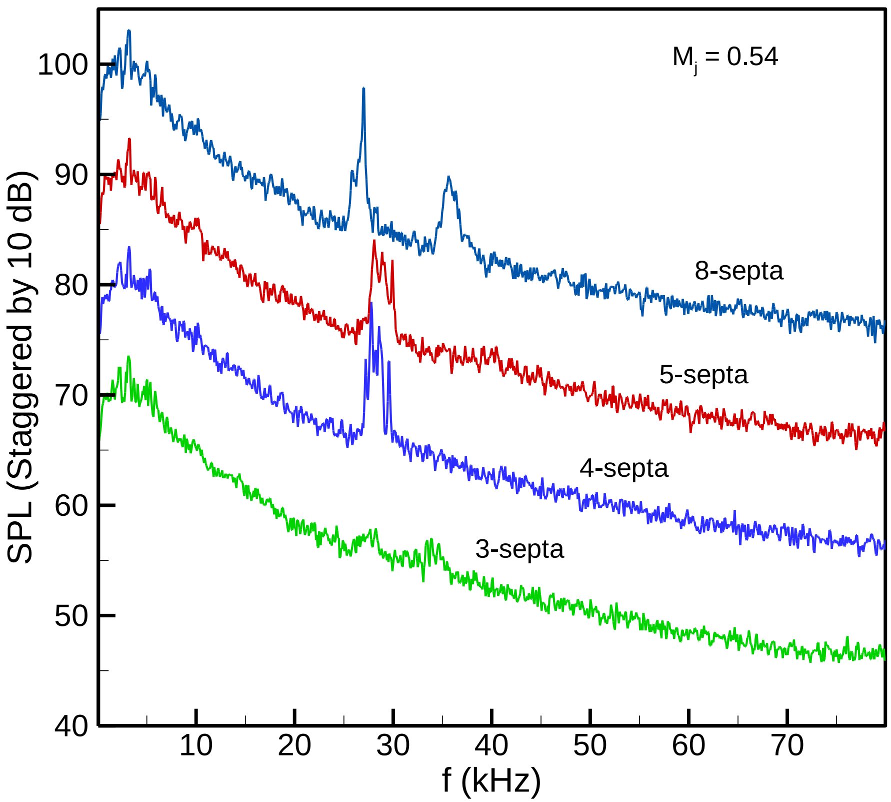
Centerline mean velocity exhibit an upstream shift of the jet for the septa case. Turbulence intensity is reduced downstream.

At lower M_j a high-frequency tone occurs that is heard prominently on the major axis. It is due to Karmann vortex shedding from the TE of partitions separating the septa.

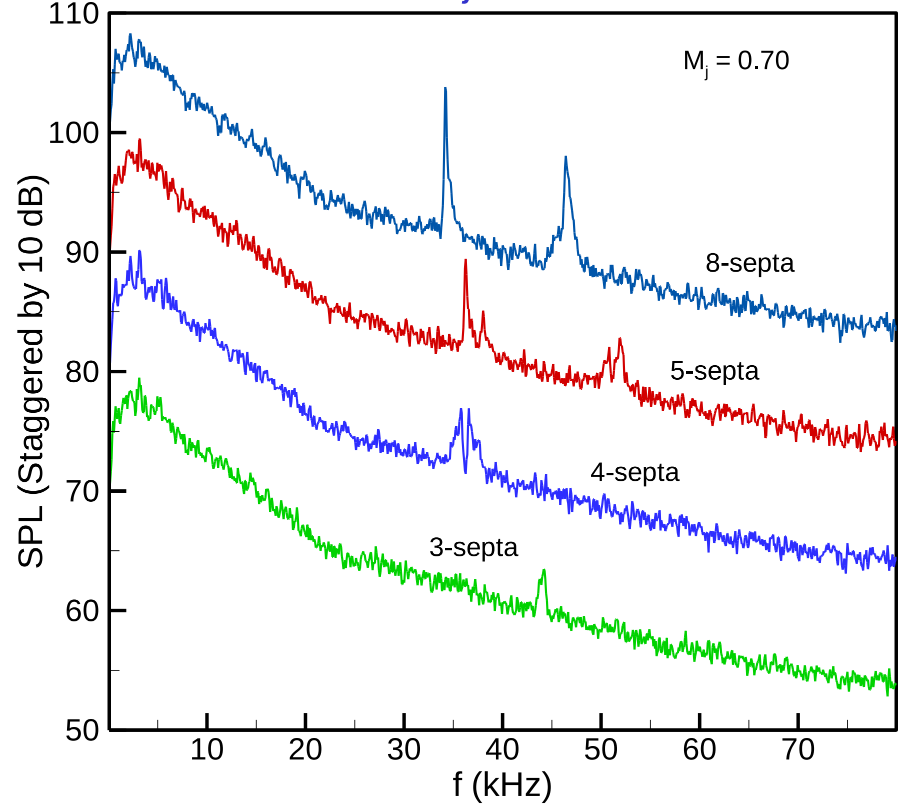
SPL spectra for Design II inserts with varying number of septa

Microphone on major axis

M_j = 0.54

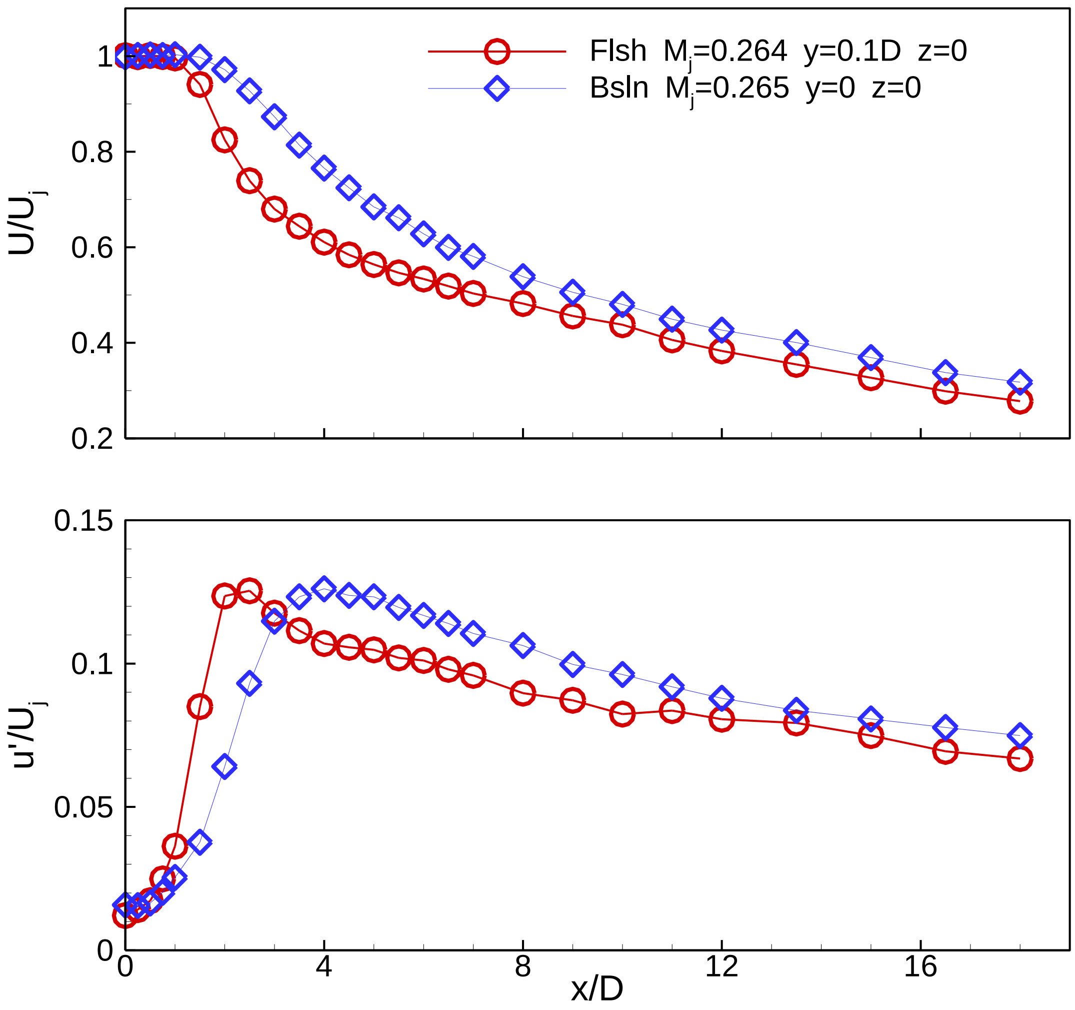


M_j = 0.70



These results demonstrate that the shedding tone intensifies with more number of septa (closer proximity of the partitions).

Centerline profiles of *U* and *u'*
Flsh vs Baseline cases; M_j = 0.265



Flsh septa case involves a faster plume decay and lower turbulence downstream